

Echoes of Recovery: Echocardiographic and Quality of Life Transformations after Percutaneous Atrial Septal Defect Closure

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Abstract

Background: Atrial septal defects (ASDs) are among the most common congenital heart diseases in adults and may lead to right heart dilation, pulmonary hypertension, and arrhythmias if left untreated. This study aims to evaluate the short and mid term effects of percutaneous transcatheter closure of secundum ASDs on right ventricular (RV) structure and function, as well as on patient reported quality of life (QoL). **Materials and Methods:** This prospective observational study was conducted at a tertiary care center and included 60 adult patients (mean age: 38.26 ± 12.58 years; 80% female) who underwent transcatheter closure of secundum ASDs. Eligible patients demonstrated significant left to right shunting (pulmonary to systemic flow ratio >1.5) with suitable septal anatomy. Exclusion criteria included severe pulmonary arterial hypertension, Eisenmenger physiology, and complex congenital heart disease. Comprehensive transthoracic echocardiography and the 12 item Short Form Health Survey (SF 12) were administered at baseline, 24 h, and 90 days post-procedure. The primary endpoints were echocardiographic indicators of RV remodeling; secondary endpoints focused on changes in QoL domains. **Results:** The mean ASD diameter was 21.85 ± 4.72 mm. By Day 90, RV basal diameter decreased from 45.00 mm to 36.93 mm ($P < 0.001$), and RV outflow tract diameter reduced from 28.82 mm to 23.23 mm ($P < 0.001$). RV fractional area change improved (32.75% to 35.20%, $P = 0.022$), and myocardial performance index declined from 0.52 to 0.36 ($P < 0.001$). QoL significantly improved across physical, emotional, and social domains. **Conclusions:** Percutaneous ASD closure leads to significant right heart remodeling and improved functional and psychosocial outcomes within 3 months.

Keywords: Atrial septal defect, echocardiography, percutaneous closure, quality of life, right ventricular function

INTRODUCTION

Congenital heart defects (CHDs) are among the most common congenital anomalies, with a global prevalence of 8–12 per 1000 live births.^[1] Atrial septal defects (ASDs) account for 10%–15% of all CHDs and nearly 40% of those diagnosed in adulthood.^[1] ASDs arise from improper septation during embryonic development, resulting in persistent interatrial communication. Among the four primary ASD subtypes, ostium secundum ASDs are the most prevalent, comprising approximately 70%.^[2] ASDs frequently remain undiagnosed in early life due to subtle or absent symptoms, leading to complications such as right ventricular (RV) volume overload, arrhythmias, and paradoxical embolism in adulthood.^[3] The left-to-right shunt associated with ASDs induces chronic RV volume overload, progressive chamber dilation, and potential right-sided heart failure.^[4] Prolonged shunting may

also lead to pulmonary arterial hypertension (PAH) in up to 10% of uncorrected cases.^[4] Structural changes resulting from ASDs increase the risk of atrial arrhythmias, including atrial fibrillation, particularly in individuals over 40 years of age.^[5]

Percutaneous ASD closure has emerged as the preferred treatment for ostium secundum ASDs, offering high success rates ($>95\%$) and fewer complications than surgical closure.^[6–8] The Amplatzer Septal Occluder remains the most widely

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used device, with Occlutech Figulla also showing clinical efficacy.^[6] Postclosure echocardiographic evaluations reveal RV remodeling, reduced atrial dilation, and improved cardiac function.^[9] This study prospectively evaluates RV remodeling following ASD closure using advanced echocardiographic modalities, addressing a notable gap in current literature, which is largely retrospective. Our novel methodology incorporates a detailed temporal analysis of RV functional recovery, thereby enriching the understanding of cardiac adaptation after closure. This research aims to offer meaningful insights into the management of congenital heart disease and interventional cardiology.

MATERIALS AND METHODS

This prospective observational study was conducted to assess the impact of percutaneous transcatheter ASD closure using both echocardiographic and quality of life (QoL) parameters. Before commencement, approval was obtained from the institutional ethical committee, and written informed consent was collected from all participants. Inclusion criteria included consenting patients diagnosed with a secundum ASD demonstrating significant left-to-right shunting ($Q_p/Q_s > 1.5$) and adequate rim anatomy suitable for transcatheter closure. Exclusion criteria comprised the presence of other congenital heart defects requiring surgical correction, severe pulmonary hypertension or Eisenmenger syndrome, contraindications to percutaneous closure (such as inadequate rim size), and comorbidities that could impact survival or follow-up compliance.

All participants underwent comprehensive echocardiographic evaluation using the Philips EPIQ ultrasound system with an S5-1 broadband (1–5 MHz) phased-array transducer for transthoracic echocardiography (TTE). Multiview imaging – including subcostal, apical four-chamber, parasternal short-axis, and, where necessary, transesophageal echocardiographic views – was utilized to assess ASD size. The maximum ASD diameter was documented, and balloon sizing was performed when necessary to measure the stretched defect size for device selection and procedural planning. RV function was assessed using multiple echocardiographic parameters. RV basal diameter was measured in the apical four-chamber view at end diastole, from the RV free wall to the interventricular septum at the tricuspid annulus level. A measurement exceeding 41 mm indicated RV enlargement secondary to volume overload. The RV outflow tract (RVOT) diameter was assessed in the parasternal short-axis view at the aortic valve level, with dilation defined as > 30 mm. The right-to-left ventricular end-diastolic diameters (RVEDD/LVEDD) ratio was evaluated in the parasternal long-axis view, with values > 0.6 indicating RV volume overload and anticipated normalization following closure. The thresholds for RV dimensions and function were adapted from the 2020 ESC Guidelines on Adult Congenital Heart Disease.^[4]

Additional functional assessments included tricuspid annular plane systolic excursion (TAPSE) and RV fractional area

change (FAC), both obtained in the apical four-chamber view. TAPSE was measured using M-mode at the lateral tricuspid annulus, with values < 17 mm indicating systolic dysfunction. RV FAC was calculated as $100 \times (RVEDA - RVESA) / RVEDA$, where RVEDA and RVESA denote end-diastolic and end-systolic areas, respectively, with $< 35\%$ signifying systolic impairment. The RV myocardial performance index (RV MPI) was calculated via pulsed-wave Doppler at the tricuspid annulus. A value > 0.54 (PW Doppler) or > 0.40 (tissue Doppler imaging [TDI]) was indicative of dysfunction. Left ventricular (LV) function was assessed through ejection fraction (LVEF), calculated using the biplane Simpson's method in parasternal long-axis and apical four-chamber views. $LVEF = (EDV - ESV) / EDV \times 100$, where EDV and ESV represent end-diastolic and end-systolic volumes. $LVEF < 50\%$ was indicative of systolic dysfunction. TDI was employed to measure peak systolic (S'), early diastolic (E'), and late diastolic (A') velocities at the lateral tricuspid annulus.

Device deployment was assessed postprocedure using echocardiographic views to evaluate the device's size, shape, position, and any residual shunting. Follow-up evaluations were conducted at 3 months, including echocardiography and QoL assessments using the SF-12 questionnaire. Echocardiographic parameters were collected preprocedure, immediately postprocedure, and at 3 months postclosure to analyze RV remodeling and hemodynamic changes. Statistical analysis was performed using IBM SPSS Statistics v25.0 (IBM Corp., Armonk, New York, USA). Data normality was assessed using the Shapiro–Wilk test. Depending on the distribution and data type, the Chi-square test, Friedman test, and Wilcoxon signed-rank test were applied. $P < 0.05$ was considered statistically significant. All ethical standards outlined by the Indian Council of Medical Research and the Declaration of Helsinki were strictly followed. Written informed consent was obtained from all participants, and confidentiality was rigorously maintained throughout the study.

RESULTS

Baseline data

The study cohort [Table 1] comprised 60 participants aged 11–70 years (mean: 38.26 ± 12.58 years). Most participants (69.9%) were between 21 and 50 years, evenly distributed across subgroups. The youngest (11–20 years) and oldest (61–70 years) represented 10% and 6.7%, respectively. There was a marked gender disparity, with females comprising 80% of the cohort. Mean height was 1.57 m (standard deviation [SD] = 0.11), and mean body weight was 57.21 kg (SD = 11.22), resulting in a mean body mass index (BMI) of 22.93 kg/m^2 (SD = 3.34). BMI categories showed 36.7% overweight, 26.7% normal, 26.7% obese Class I, and 10% underweight; no participants were in obese Class II. Regarding comorbidities, 13.3% had prior cardiovascular disorders and 6.7% had cerebrovascular issues. Diabetes mellitus and hypertension were present in 33.3% and 30%, respectively. Smoking was reported by 16.7% of participants.

Quality of life assessment

Comparison of SF-12 responses pre- and post-ASD closure [Table 2] revealed significant improvements across physical and emotional health domains. Before intervention, 60% rated their general health as fair, and 23.3% as poor. Postprocedure, 56.7% described their health as very good, and 16.7% as excellent, though not statistically significant. Significant improvement was noted in physical functioning: 46.7% had severe limitations preprocedure, compared to only 3.3% afterward; 70% reported no limitations at all ($P = 0.012$). Although stair climbing also showed improvement, this change was not statistically significant.

Work limitations due to physical health dropped from 90% preprocedure to 20% postprocedure, while emotional health-related limitations also declined. Emotional well-being improved considerably, with only 20% feeling persistently downhearted postprocedure compared to 53.3% prior ($P = 0.001$). Pain interference in daily work showed significant improvement; 80% reported no such interference after the procedure ($P = 0.004$). Similarly, energy levels rose postprocedure: 43.3% felt energetic all the time, compared to 50% who previously reported only occasional or no energy ($P = 0.001$). Social participation improved, with 50% reporting no limitations due to health, also highly significant ($P = 0.001$). SF-12 component scores [Table 3] further supported these improvements. The PCS-12 score increased from 52.46 ± 0.57 to 52.68 ± 0.44 ($P = 0.010$), while

MCS-12 improved more markedly – from 54.41 ± 0.60 to 54.84 ± 0.58 ($P = 0.001$), underscoring the positive impact of ASD closure on both physical and mental well-being.

Echocardiographic assessment

Echocardiographic evaluation demonstrated significant right heart remodeling post-ASD closure. ASD sizes ranged from 14 to 32 mm (mean: 21.85 ± 4.72 mm), with the 21–25 mm range being the most common (36.7%). RV basal diameter declined significantly from 45.00 mm (SD = 4.62) preprocedure to 38.23 mm on day 1 and 36.93 mm by day 90 ($P < 0.001$). RVOT diameter decreased from 28.82 mm to 23.23 mm ($P < 0.001$). The RVEDD/LVEDD ratio also fell significantly from 1.13 to 0.82 ($P < 0.001$), indicating resolution of RV volume overload.

Functional improvements paralleled structural changes. TAPSE increased from 18.80 mm (SD = 3.77) to 23.03 mm (SD = 2.04) ($P < 0.001$). RV end-systolic area reduced from 11.96 cm² to 9.20 cm², and RV end-diastolic area from 17.83 cm² to 14.31 cm² ($P < 0.001$ for both), reflecting effective remodeling. RV FAC improved from 32.75% to 35.20% ($P = 0.022$), and RV MPI decreased from 0.52 to 0.36 ($P < 0.001$) [Figure 1], indicating enhanced RV function. In addition, right atrial size significantly declined, reinforcing the reversal of volume overload. Although TAPSE and FAC are traditionally considered volume-dependent indices and typically decline with decreased preload following ASD closure, our cohort showed a paradoxical increase. This could reflect rapid functional adaptation of the RV, likely due to intrinsic myocardial recovery and enhanced contractile efficiency postdecompression. Similar findings were reported by Huang *et al.* (2020),^[10] where RV work indices improved despite volume normalization.

Comparative analysis of echocardiographic parameters among different age groups

A comparative analysis [Table 4] of echocardiographic parameters across three age groups (18–35, 36–50, and >51 years) revealed statistically significant baseline differences in RV basal diameter ($P = 0.005$), RVED/LVED ratio ($P = 0.004$), RVFAC ($P = 0.040$), RVMPI ($P = 0.005$), RA major dimension ($P = 0.003$), and LVEF ($P = 0.024$). Postprocedure, significant differences persisted at various time

Table 1: Baseline characteristics

Characteristics	Value
Age	
Age (years), mean±SD	38.26±12.58
Age range (years)	18–62
Gender, n (%)	
Male	12 (20)
Female	48 (80)
Physical characteristics, mean (range)	
Height (m)	1.57±0.11 (1.30–1.80)
Weight (kg)	57.21±11.22 (36.3–76)
BMI (kg/m ²)	22.93±3.34 (14.7–28.4)
BSA (m ²)	1.56±0.19 (1.19–1.92)
BMI category – underweight, n (%)	6 (10)
BMI category – overweight, n (%)	22 (36.7)
BMI category – normal, n (%)	16 (26.7)
BMI category – obese, n (%)	16 (26.7)
Co-morbidities, n (%)	
Prior CVS disorders (except ASD)*	8 (13.3)
Prior CNS disorders	4 (6.7)
Diabetes mellitus	20 (33.33)
Hypertension	18 (30)
Cigarette smokers	
Smokers	10 (16.67)

* $P < 0.05$ is considered statistically significant. Data are presented as mean±SD or number and percentage, as appropriate. ASD: Atrial septal defect, BMI: Body mass index, BSA: Body surface area, CNS: Central nervous system, CVS: Cardiovascular system, SD: Standard deviation

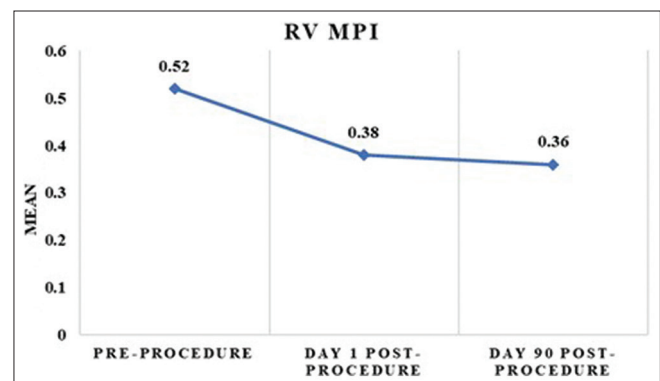


Figure 1: Changes in right ventricular myocardial performance index over time. RV MPI: Right ventricular myocardial performance index

Table 2: Summary of Short Form 12 Questionnaire – most frequent responses pre- and post-procedure and significant changes over 3 months

Question numbers	Questions	Most common preprocedure response (%)	Most common postprocedure response (%)	χ^2 ; <i>P</i>
1	In general, would you say your health is	Fair (4): 60.0	Very good (2): 56.7	8.471; 0.153
2	Limitation of moderate physical activities?	Yes, limited a little (2): 50.0	No, not limited at all (3): 70.0	10.653; 0.012*
3	Limitation in climbing several flights of stairs	Yes, limited a lot (1): 70.0	No, not limited at all (3): 56.7	5.512; 0.245
4	During the past 4 weeks, have you had any of the following problems with your work or other regular activities as a result of your physical health? Accomplished less than you would like?	Yes (1): 90.0	No (2): 80.0	1.667; 0.333
5	During the past 4 weeks, have you had any of the following problems with your work or other regular activities as a result of your physical health? Were limited in the kind of work or other activities?	Yes (1): 86.7	Yes (1): 83.3	1.846; 0.330
6	During the past 4 weeks, you had any of the following problems with your work or other regular activities as a result of your emotional problems? Accomplished less than you would like?	Yes (1): 63.3	No (2): 80.0	2.584; 0.180
7	During the past 4 weeks, have you had any of the following problems with your work or other regular activities as a result of your emotional problems? Didn't do work or other activities as carefully as usual?	Yes (1): 73.3	No (2): 83.3	0.273; 0.715
8	During the past 4 weeks, how much PAIN interfered with your normal work (including both work outside the home and housework)?	Moderately (3): 30.0	Not at all (1): 80.0	16.963; 0.004*
9	During the past 4 weeks, have you felt calm and peaceful?	A little of the time (5): 53.3	All the time (1): 50.0	26.740; 0.063
10	During the past 4 weeks, did you have a lot of energy?	A little of the time (5): 50.0	All the time (1): 43.3	22.901; 0.001*
11	During the past 4 weeks, have you felt downhearted and blue?	Most of the time (2): 53.3	A little of the time (5): 43.3	52.76; 0.001*
12	During the past 4 weeks, how many times have your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.?)	Most of the time (2): 50.0	None of the time (6): 50.0	22.752; 0.001*

**P*<0.05 is considered statistically significant and is marked with an asterisk. Data represent the most frequent participant responses to each question of the SF-12 health survey before and after ASD closure. Statistical analysis was performed using the Chi-square test. Response codes correspond to the SF-12 scoring scale. ASD: Atrial septal defects, SF: Short form

Table 3: Short Form-12 comparison over a period of time

SF-12	Preprocedure		Postprocedure		Difference	<i>P</i>
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	
PCS-12	52.46±0.57	52.37 (52.12–52.94)	52.68±0.44	54.43 (53.97–54.92)	0.22±0.66	0.010*
MCS-12	54.41±0.60	52.68 (52.25–53.03)	54.84±0.58	54.89 (54.49–55.33)	0.42±0.92	0.001*

**P*<0.05 is considered statistically significant. Values are presented as mean±SD and median with IQR. Statistical analysis performed using the Wilcoxon signed-rank test. IQR: Interquartile range, PCS-12: Physical component summary, MCS-12: Mental component summary, SD: Standard deviation, SF: Short form

points for RV basal diameter (day 90, *P*=0.014), RVED/LVED ratio (day 1 and 90, *P*=0.001 and 0.021, respectively), RVOT diameter (day 1, *P*=0.027), RVFAC (day 90, *P*=0.044), and RA dimension (day 1 and 90, *P*=0.001 and 0.003). Parameters such as TAPSE, RV systolic area, and LVEF showed no significant intergroup differences postprocedure. Notably, younger patients demonstrated more consistent reverse remodeling over time.

DISCUSSION

Baseline data

The demographic profile of the study cohort aligns with known patterns of ASD presentation, with most patients

between 21 and 50 years and a marked female predominance. Similar age-related trends have been observed in prior studies, where early intervention favored better outcomes and more pronounced RV remodeling.^[11] The female majority (80%) is consistent with known epidemiological distributions^[11,12] and highlights the need for targeted adult congenital heart screening, particularly in women with unexplained right heart changes. Anthropometric data – mean BMI of 22.93 kg/m² and BSA of 1.56 m² – correspond with previous cohort studies.^[13,14] These parameters are important when interpreting remodeling outcomes, as RV dimensions can be influenced by body habitus. Studies by Mangiafico *et al.*^[15] and Ammar *et al.*^[16] have suggested BMI may subtly influence RV

Table 4: Comparison of mean echocardiographic parameters across age groups before and after atrial septal defect device closure

Parameter Mean	Time point	Age groups (years)			P
		18–35	36–50	>51	
RV basal diameter (mm)	Pre	42.58	46.92	46	0.005*
	Day 1	37	38.9	39.33	0.062*
	Day 90	35.33	37.67	38.67	0.014*
RVOT diameter (mm)	Pre	28.58	29.88	27.17	0.118
	Day 1	24.5	23.83	22	0.027*
	Day 90	23.67	23.17	22.5	0.242
RVED/LVED ratio	Pre	1.12	1.22	0.98	0.004*
	Day 1	0.86	0.96	0.78	0.001*
	Day 90	0.8	0.88	0.75	0.021*
TAPSE (mm)	Pre	19.08	18.08	19.67	0.58
	Day 1	21.83	23	22.67	0.121
	Day 90	22.67	23.42	23	0.411
RV systolic area (cm ²)	Pre	12.01	12.11	11.6	0.468
	Day 1	9.62	9.74	8.6	0.213
	Day 90	9.35	9.48	8.33	0.15
RV FAC (%)	Pre	31.26	32.15	36.96	0.04*
	Day 1	33.18	33.76	40.13	0.072*
	Day 90	33.16	34.27	41.16	0.044*
RVMPI	Pre	0.498	0.556	0.498	0.005*
	Day 1	0.364	0.42	0.368	0.051
	Day 90	0.352	0.383	0.355	0.119
RA major dimension (mm)	Pre	43.17	49.08	41.5	0.003*
	Day 1	36.25	42.5	34.17	0.001*
	Day 90	34.83	40.08	32.83	0.003*
LVEF (%)	Pre	59.75	55.67	57.67	0.024*
	Day 1	59.25	59.25	58.67	0.566
	Day 90	59.5	59.25	59.33	0.942

* $P < 0.05$ was considered statistically significant. Data are presented as mean values for each age group (18–35 years, 36–50 years, and >51 years) at three time points: preprocedure, 1 day postprocedure, and 90 days postprocedure. ASD: Atrial septal defect, LVEF: Left ventricular ejection fraction, RA: Right atrium, RV: Right ventricle, RV basal diameter: Right ventricular basal diameter, RVED/LVED Ratio: Right ventricular to left ventricular end-diastolic diameter ratio, RVFAC: Right ventricular fractional area change, RVMPI: Right ventricular myocardial performance index, RV systolic area: Right ventricular systolic area, RVOT: Right ventricular outflow tract, TAPSE: Tricuspid annular plane systolic excursion

recovery, reinforcing the need for indexed measurements in postclosure evaluation.

Comorbidities and clinical implications

The high prevalence of hypertension and diabetes in this cohort reflects a common overlap between congenital and acquired cardiovascular pathology. These comorbidities, if uncontrolled, may attenuate the benefits of ASD closure by impairing myocardial adaptability.^[17] Prior work by Engelfriet *et al.*^[18] and Bosshardt *et al.*^[11] linked continued smoking to delayed hemodynamic normalization after closure. Similarly, it is emphasized that early closure improves long-term outcomes, especially when metabolic risk factors are managed concurrently. Notably, 16.7% of patients were smokers – an

important modifier in pulmonary pressure regression. Prior work by Engelfriet *et al.*^[18] and Bosshardt *et al.*^[11] linked continued smoking to delayed hemodynamic normalization after closure. Smoking cessation should therefore be part of structured postprocedural rehabilitation to optimize outcomes.

Quality of life

The improvement in QoL observed postclosure is clinically meaningful and consistent with earlier studies that reported enhanced physical endurance and psychosocial recovery.^[10,19] Fatigue reduction and increased energy levels point to improved cardiac output and tissue perfusion, suggesting that anatomical correction translates into tangible daily benefits. Significantly higher postprocedure scores in both physical (PCS-12) and mental (MCS-12) summary domains echo the findings of Huang *et al.*^[10] and Mirmohammadsadeghi *et al.*^[19] Importantly, these gains were not just subjective but mirrored objective improvements in RV function, supporting a unified framework of structural and symptomatic recovery. Prior work has underlined the psychological burden of undiagnosed congenital heart defects,^[10] and our findings reinforce the importance of addressing mental health as a legitimate endpoint of cardiovascular intervention.

Echocardiographic findings

The marked RV remodeling observed in our cohort [Table 5] reflects the heart's adaptability once the volume overload of ASD is relieved. Within 90 days, significant reductions in RV basal and outflow tract dimensions occurred, confirming a rapid anatomical response. Akula *et al.*^[20] previously documented similar trends, particularly in defects >20 mm, emphasizing that even longstanding volume overload may be reversible with timely closure. In line with Enache *et al.*^[21] and Kumar *et al.*,^[12] our data showed a concurrent improvement in RV FAC and MPI, suggesting not just geometric normalization but functional recovery. Veldtman *et al.*^[9] found persistent RV dilation in a subset of patients despite closure, reinforcing the need for serial imaging, especially in large ASDs.

The decline in RVEDD/LVEDD ratio further supports a shift toward normal biventricular geometry. Improvement in TAPSE and RA dimensions postclosure confirms that hemodynamic load redistribution benefits both systolic performance and atrial unloading.^[20,21] RVOT reduction in particular has been underexplored but emerged here as a sensitive marker of remodeling, as also noted by Monfredi *et al.*^[22] LVEF remained stable across all time points, consistent with findings by Mangiafico *et al.*^[15] This is crucial from a safety standpoint, indicating that ASD closure does not negatively impact LV systolic function even when dramatic RV shifts occur.

The comparative analysis among the different age groups [Table 4] suggests that age plays a considerable role in baseline cardiac structure and its remodeling following ASD device closure. Younger patients (18–35 years) showed greater reversibility in RV dimensions and functional indices, particularly in RV basal diameter and RVED/LVED ratio,

Table 5: Comparison of echocardiographic parameters over time

Parameters	Preprocedure, mean (range)	Postprocedure, day 1, mean (range)	Postprocedure, day 90, mean (range)	χ^2 ; <i>P</i>
Defect size	21.85±4.72 (14–32)			
RV basal diameter (mm)	45±4.62 (38–52)	38.23±3.71 (31–44)	36.93±3.79 (30–42)	107.38; 0.001*
RVOT PSAX Diameter (mm)	28.82±3.62 (22–38)	23.73±3.05 (20–31)	23.23±2.94 (19–31)	102.05; 0.001*
RVEDD/LVEDD ratio (mm)	1.13±0.22 (0.80–1.60)	0.88±0.13 (0.80–1.00)	0.82±0.14 (0.70–0.90)	107.33; 0.001*
TAPSE (mm)	18.80±3.77 (12–26)	22.46±2.22 (19–27)	23.03±2.04 (19–27)	84.62; 0.001*
RV systolic area	11.96±1.40 (9.4–14.6)	9.46±1.84 (5.9–12.9)	9.20±1.74 (6–12)	107.93; 0.001*
RV diastolic area	17.83±2.05 (15–23)	14.63±2.60 (10.6–21.2)	14.31±2.49 (10.4–20.5)	107.93; <0.001*
RV FAC	32.75±5.14 (19.73–45.68)	34.80±10.42 (15.09–56.41)	35.20±10.22 (18.18–57.35)	7.60; 0.022*
RV MPI	0.52±0.06 (0.36–0.62)	0.38±0.07 (0.28–0.60)	0.36±0.04 (0.28–0.47)	99.86; 0.001*
RA major dimension	45.20±7.43 (31–66)	38.33±7.15 (25–55)	36.53±6.96 (23–52)	107.79; 0.001*
LVEF	57.70±5.40 (37–66)	59.13±4.08 (50–66)	59.36±3.92 (52–66)	1.17; 0.557

**P*<0.05 is considered statistically significant. Values are expressed as mean±SD with corresponding range. Statistical significance assessed using the Friedman test. FAC: Fractional area change, LVEF: Left ventricular ejection fraction, LVEDD: Left ventricular end-diastolic diameter, MPI: Myocardial performance index, PSAX: Parasternal short axis, RA: Right atrium, RV: Right ventricle, RVEDD: Right ventricular end-diastolic diameter, RVOT: Right ventricular outflow tract, SD: Standard deviation, TAPSE: Tricuspid annular plane systolic excursion

indicating more plasticity and favorable adaptation. Older patients (>51 years) exhibited higher baseline RVFAC and RA dimensions, with more persistent postprocedure dilation, possibly reflecting chronic volume overload and reduced myocardial compliance. The consistent improvement in RV function across age groups, albeit with varying degrees, reinforces the benefits of timely intervention. TAPSE and LVEF remained stable across age brackets, implying preserved global systolic function in all groups.

CONCLUSIONS

This study affirms that percutaneous ASD closure leads to early and substantial right heart remodeling, with improvements extending from anatomical normalization to functional recovery and enhanced QoL. The short-term echocardiographic changes, evident as early as 3 months, underscore the value of early intervention before irreversible changes such as fibrosis or pulmonary vascular remodeling set in. By combining validated echocardiographic metrics with SF-12-based patient-reported outcomes, this study offers a comprehensive view of procedural success. Unlike many retrospective series, our prospective design enables confident attribution of observed improvements to the intervention itself. However, the single-center nature of the study and the relatively short follow-up period limit the generalizability and long-term interpretation of the findings. In addition, the absence of a control group restricts comparative analysis with surgical or conservatively managed cohorts. Future multicenter studies with longer follow-up are needed to determine the durability of these gains and evaluate whether early closure may also reduce the incidence of late complications such as arrhythmia and right heart failure. The integration of objective cardiac remodeling indices with subjective health metrics presents a model for holistic outcome assessment in adult congenital heart disease.

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Authors' contributions

VA, AT, SG: Concept. AT, SG: Design. AT, VA: Definition of intellectual content. AT, SG, PR, MK: Literature search. AT, SG, MK, PR: Clinical studies. AT, PR, MK, SG: Data acquisition. AT, SG, VA: Data analysis. AT, SG: Statistical analysis. AT, SG, VA: Manuscript preparation. AT, PR, SG, VA: Manuscript editing. All authors: Manuscript review.

Data availability statement

The study data will be provided upon request.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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